PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

To:

BLUFF, John, William
Lloyd Wise, Tregear & Co.
Commonwealth House
1-19 New Oxford Street
London WC1A 1LW
ROYAUME-UNI

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

Date of mailing (day/month/year)
22 June 2001 (22.06.01)

Applicant's or agent's file reference
JWB/SS/44774

IMPORTANT NOTIFICATION

International application No.
PCT/EP00/10022

International filing date (day/month/year)
10 October 2000 (10.10.00)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address
FAST TECHNOLOGY GMBH.
Otto Hahn Str. 24
Gewerbegebiet Riemerling
85521 Ottobrunn
Germany

State of Nationality: DE
State of Residence: DE
Telephone No.:
Facsimile No.:
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [ ] the address [ ] the nationality [ ] the residence

Name and Address
FAST TECHNOLOGY AG
Otto Hahn Str. 24
Gewerbegebiet Riemerling
85521 Ottobrunn
Germany

State of Nationality: DE
State of Residence: DE
Telephone No.:
Facsimile No.:
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[ ] the International Preliminary Examining Authority
[X] the designated Offices concerned
[ ] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

Authorized officer
Jean-Marie McAdams
Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 06 July 2001 (06.07.01)	
International application No. PCT/EP00/10022	**Applicant's or agent's file reference** JWB/SS/44774
International filing date (day/month/year) 10 October 2000 (10.10.00)	**Priority date** (day/month/year) 11 October 1999 (11.10.99)
Applicant MAY, Lutz, Axel	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

03 May 2001 (03.05.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

Odile ALIU

Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
JWB/SS/44774		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP 00/10022	10/10/2000	11/10/1999
Applicant		
FAST TECHNOLOGY GMBH		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 7

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
[illegible]/EP 00/10022

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01L3/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 434 089 A (ASEA BROWN BOVERI) 26 June 1991 (1991-06-26) the whole document ---	1-11
X	GB 968 503 A (BRISTOL SIDDELEY ENGINES LTD) 2 September 1964 (1964-09-02) the whole document -----	12,13

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 February 2001	21/02/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Nobrega, R.

1

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
[redacted]/EP 00/10022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0434089 A	26-06-1991	SE 465185 B	05-08-1991
		CA 2032584 A	22-06-1991
		DE 69012075 D	06-10-1994
		ES 2063239 T	01-01-1995
		JP 3030096 B	10-04-2000
		JP 4120431 A	21-04-1992
		SE 8904307 A	22-06-1991
		US 5122742 A	16-06-1992
GB 968503 A		NONE	

Box III TEXT OF THE ABSTRACT (Continuation of Item 5 of the first sheet)

The abstract is changed as follows:

Line 7: "the motor" are deleted.
Line 10: after "field (60)." line is deleted.
Line 11 to 27 are deleted.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP00/10022	10/10/2000	11/10/1999
International Patent Classification (IPC) or national classification and IPC G01L3/10		
Applicant FAST TECHNOLOGY AG et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 1 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☒ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☒ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
03/05/2001	02.01.2002
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Gerken, S Telephone No. +49 89 2399 6511

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP00/10022

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-14	as originally filed				

Claims, No.:

7-13	as originally filed				
1-6	as received on	16/11/2001	with letter of	15/11/2001	

Drawings, sheets:

1/3-3/3	as originally filed				

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

   ☐ the entire international application.

   ☒ claims Nos. 4.

because:

   ☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

   ☐ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. are so unclear that no meaningful opinion could be formed (*specify*):

   ☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

   ☒ no international search report has been established for the said claims Nos. 4.

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

   ☐ the written form has not been furnished or does not comply with the standard.

   ☐ the computer readable form has not been furnished or does not comply with the standard.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	5-13
	No:	Claims	1-3
Inventive step (IS)	Yes:	Claims	5-13
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-3,5-13
	No:	Claims	

2. Citations and explanations
see separate sheet

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

and / or

2. Non-written disclosures (Rule 70.9)

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item III

Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. Claim 4 relates to a collar structure carried by the shaft. As this feature was not present in the original set of claims it has not been searched. Hence, no opinion with regard to the requirements of Art. 33(2), (3) and (4) can be established.

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents:
   D1: EP-A-0 434 089 (ASEA BROWN BOVERI) 26 June 1991
   D2: GB 968 503 A (BRISTOL SIDDELEY ENGINES LTD) 2 September 1964

Negative statements

2. Lack of novelty, Art. 33(2) PCT

2.1. With respect to **claim 1** the document D1 (see Figs. 2, 3, 9 and 10 with related description) shows a torque transducer for measuring torque in a rotating shaft (40) having a transducer region (42,43) in which a magnetic transducer field is established and at least one non-contacting sensor (implicit, arranged to be close to regions 42,43) adjacent the transducer region to develop a torque-dependent signal, wherein in operation the shaft is subject to longitudinal flux generated by means external to the transducer region, and a non-contacting sensor (9 in Figs. 2 and 3) responsive (by virtue of being able to sense even harmonics of the fundamental frequency with which the excitation winding 5 is driven) to a component of said longitudinal flux to develop (by phase-sensitive detection of the even harmonics which are due to a distortion of a B-H-loop) a signal representing the level of said longitudinal flux, and means 5,14,44,45) responsive to the level-representing signal for said longitudinal flux and magnetically coupled to said shaft (40) to generate a compensating flux to counteract said longitudinal flux at the transducer region (cf. the DC-component provided by the regulator 12 in Figs. 2 and 3. Hence, all features of claim 1 are known in combination from D1.

2.2. The additional features of the following dependent claims are also known from D1:

- **claim 2:** means for generating the compensating flux comprises at least one current-carrying coil, cf. any of coils 14 in Fig. 2 and 9, 5 in Fig. 3 and 44,45 in Fig. 10
- **claim 3:** poles spaced along the shaft, cf. yoke 46 in Fig. 10

Positive statements

3. The torque transducers of the independent **claims 5 and 7** differ from the device according to D1 at least in that they define a sensor placed in non-contacting fashion adjacent a portion of the shaft to sense and provide a signal dependent on a transverse component of flux arising from the longitudinal flux due to the torque in the shaft. Hereby the problem is solved to enable a potentially interfering field to be used as the torque-sensitive field for measuring torque. D1 is quiet with respect to directions of flux-components to be sensed by the torque-sensitive element. D2 is based on a different approach (see below). Hence, claims 5 and 7 fulfil the requirements of novelty and inventive step.

4. The torque transducer of the independent **claim 12** comprises an erase head, a write head downstream of the erase head in the direction of rotation to write a magnetic track and a pair of read heads spaced in an axial direction to respond to the magnetic track, to generate respective signals, and differential means responsive to said respective signals of the read heads to provide a signal dependent on the torque in the shaft. In contrast thereto, D2 shows two transducer assemblies, each having a read head for reading a respective permanently-written modulated magnetic track, whereby the phase difference of the signals provided by the read heads is evaluated in order to obtain the torque. D1 does not use write or read heads. Hence, also claim 5 fulfils the requirements of novelty and inventive step.

5. **Claims 2,3,6,8-11 and 13** are truly dependent claims relating to preferred embodiments of the torque transducers of claims 1,5, 7 or 12. Hence, they fulfil also the requirements of novelty and inventive step.

6. The industrial applicability is evidently given for the subject-matter of all claims.

Re Item VI

Certain documents cited

Certain published documents (Rule 70.10)

Application No Patent No	Publication date *(day/month/year)*	Filing date *(day/month/year)*	Priority date *(valid claim)* *(day/month/year)*
WO 01/13081	22.02.2001	14.08.2000	12.08.1999

This document (mentioned under the international application number PCT/GB00/03119 in the description on page 7) appears to be novelty-destroying at least for claim 5.

Re Item VII

Certain defects in the international application

1. The relevant background art disclosed in the documents D1 and D2 has not been mentioned in the description, Rule 5.1(a)(ii) PCT.

Re Item VIII

Certain observations on the international application

1. Although claims 5 and 7 have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought and/or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness, Art. 6 PCT.

2. The description has not been brought into conformity with the amended claims.

CLAIMS

1. A torque transducer for measuring torque in a rotating shaft (61) of the kind having a transducer region (64), for example a region storing a permanent magnetisation, in which a magnetic transducer field is established and at least one non-contacting sensor (7: 22: 23) adjacent the transducer region (64) to develop a torque-dependent signal, wherein in operation the shaft (61) is subject to longitudinal flux (60) generated by means (63) external to the transducer region (64), characterised by a non-contacting sensor (97: 21: 24) responsive to a component of said longitudinal flux to develop a signal representing the level of said longitudinal flux, and means (65) responsive to the level-representing signal for said longitudinal flux and magnetically coupled to said shaft (61) to generate a compensating flux to counteract said longitudinal flux at the transducer region (64).

2. A torque transducer as claimed in Claim 1 wherein said means for generating the compensating flux comprises at least one current-carrying coil (L1, L2) about the shaft to be magnetically coupled thereto.

3. A torque transducer as claimed in Claim 1 said means (65) for generating the compensating flux comprises a magnetic structure (70) having poles (72a, 72b) spaced along the shaft (61) and at least one current-carrying coil (L3, L4) wound on said magnetic structure (70).

4. A torque transducer as claimed in Claim 1, 2 or 3 in which said shaft carries a collar structure (20) comprising two axially-spaced portions in the space (25) between which is disposed the sensor (24) responsive to the component of longitudinal flux.

5. A torque transducer for measuring the torque in a rotating shaft (61) which, in operation, has a longitudinal field (60) extending therealong, wherein at least one sensor (23) is placed in non-contacting fashion adjacent a portion of the shaft to sense and provide a signal dependent on a transverse component of flux arising from the longitudinal flux due to the torque in the shaft (61).

6. A torque transducer as claimed in Claim 5 in which a further non-contacting sensor (24) is mounted to sense the longitudinal flux to provide a reference signal

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 April 2001 (19.04.2001)

PCT

(10) International Publication Number
WO 01/27584 A1

(51) International Patent Classification[7]: G01L 3/10

(21) International Application Number: PCT/EP00/10022

(22) International Filing Date: 10 October 2000 (10.10.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9924046.7 11 October 1999 (11.10.1999) GB

(71) Applicant *(for all designated States except US)*: FAST TECHNOLOGY GMBH. [DE/DE]; Otto Hahn Str. 24, Gewerbegebiet Riemerling, 85521 Ottobrunn (DE).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: MAY, Lutz, Axel [DE/DE]; Wolfratshauser Strasse 23a, 82538 Gelting (DE).

(74) Agent: BLUFF, John, William; Lloyd Wise, Tregear & Co., Commonwealth House, 1-19 New Oxford Street, London WC1A 1LW (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

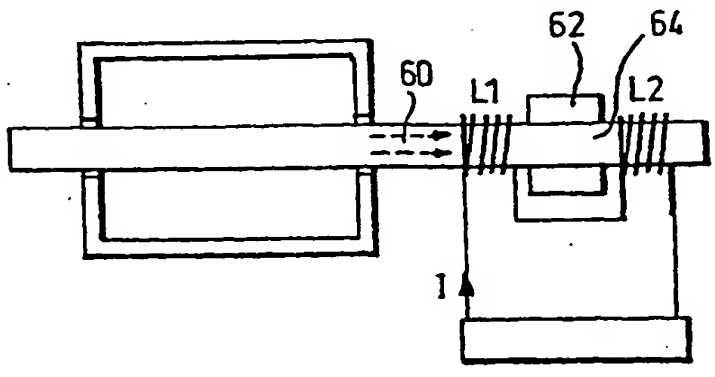
(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: TORQUE MEASUREMENT APPARATUS

WO 01/27584 A1



(57) Abstract: Torque in a shaft (61) is detected by means of non-contacting sensors (23, 24) sensing a torque-dependent magnetic field emanated by an integral transducer region (64, 32) of the shaft (61) that is circumferentially or longitudinally magnetised. The shaft (61) is driven by a motor (63) and subject to a longitudinal magnetic field (60) which acts on interference field. In one implementation of the invention coils (L1, L2: L3, L4) are energised to provide a counteracting magnetic field to compensate the interference field (60).

TORQUE MEASUREMENT APPARATUS

FIELD OF THE INVENTION

The present invention relates to the measurement of torque generated in a drive shaft. More particularly, it concerns the non-contacting measurement of such torque using magnetised transducers and seeks to compensate for, eliminate or avoid the effects of interfering magnetic fields.

BACKGROUND TO THE INVENTION

There have been prior proposals to use magnetised transducer elements for torque measurement, the transducer elements being a ring attached to a torqued shaft or the shaft itself. In this connection reference is made to U.S. Patents 5351555, 5465627 and 5520059 and to published PCT Applications WO99/21150, WO99/21151 and WO99/56099. In these specifications the ring or shaft is of magnetoelastic material circumferentially magnetised, that is the magnetisation forms a closed loop around the shaft. While such transducer elements are usable in the practice of this invention, other patterns of magnetisation are usable and do not necessarily rely on magnetoelasticity, and other shapes of transducer element may be employed. One other pattern of magnetisation which may be employed in the practice of this invention longitudinal magnetisation of the transducer region. One form of longitudinal magnetisation is disclosed in International patent application PCT/GB00/03119 filed 14th August 2000 and published under the number WO/

It is a feature of transducers systems employing magnetised transducer elements of the kind outlined above, that the torque dependent field component provided by the transducer element can be sensed by one or more sensors

adjacent to but not in contact with the transducer elements. Non-contacting sensor arrangements are of particular value in torque measurement on rotating shafts.

The above techniques are based on magnetic principles and therefore can be affected by other interfering magnetic fields, like the earth's magnetic field or fields generated by electric motors for example. In some environments where it is desirable to measure shaft torque, very strong magnetic fields may be present, particularly in the longitudinal axis of the sensing system. A typical application of this nature is the extended axis of an electric motor having a shaft projecting from the motor.

SUMMARY OF THE INVENTION

The present invention is predicated on a number of different approaches. A first may be broadly expressed as compensating or counteracting an interfering magnetic field. A second may be broadly expressed as a selective signal approach, particularly by introducing a frequency selective element into the torque-dependent magnetic flux to be measured that enables it to be distinguished from signals due to an interfering field. A third approach is to turn the "interfering" magnetic field to use and employ it as a source field from which to obtain a torque-dependent component. A fourth approach is a new way of measuring torque to which a frequency selective element may be applied. It is possible to use combinations of these approaches, particularly in combining the first approach with the second or third.

One implementation of the present invention according to the first approach above-mentioned provides a torque transducer for measuring torque in a rotating shaft of the kind having a transducer region in which a magnetic

transducer field is established and at least one non-contacting sensor adjacent the transducer region to develop a torque-dependent signal, wherein in operation the shaft is subject to longitudinal flux generated by means external to the transducer region, characterised by means magnetically coupled to said shaft to generate a compensating flux to counteract said longitudinal flux at the transducer region.

Preferably, the means coupled to the shaft for generating the compensating flux comprises at least one current-carrying coil about the shaft. It may comprise a pair of axially spaced coils between which the transducer region is situate. In the alternative or additionally, a magnetic structure may also be provided which has poles axially spaced along the shaft and at least one coil is wound about said magnetic structure.

An implementation of the invention according to the third approach above-mentioned provides a torque transducer for measuring the torque in a rotating shaft which, in operation, has a longitudinal field extending therealong, wherein at least one sensor is placed in non-contacting fashion adjacent a portion of the shaft to sense and provide a signal dependent on a transverse component of flux arising from the longitudinal flux in response to the torque in the shaft. More specifically a transverse component is transverse to the axis of rotation and at the surface of the shaft portion is usually detected as a component in the circumferential or tangential direction. In the preferred embodiment, at least one further non-contacting sensor is mounted to sense the longitudinal flux to provide a reference signal dependent thereon against which to measure the transverse component for use in obtaining a value for the torque in the shaft.

In yet another implementation of the invention, this time

in accord with the second, selective signal approach above-mentioned, a torque transducer for measuring the torque in a rotating shaft includes a portion or region of the shaft which acts as a transducer element and which is disposed between a pair of coils encircling the shaft and connected to induce a longitudinal magnetic field through the transducer region upon energisation of the coils. The coils are connected to an AC source, preferably a pulsed source, operating at a selected frequency so that the transducer region is subject to a magnetic field of alternating polarity. A sensor arrangement is responsive to a torque-dependent component of the alternating magnetic field and provides an AC output processed in a frequency-selective manner linked to the source frequency to extract the wanted component from any other noise (DC or AC) that may be present. The frequency-selective processing may be by way of a hardware or software implemented filter operating at the selected frequency linked with the AC source to synchronize the filter frequency to the source frequency. A synchronous detection scheme can be used detecting the sensor output signal with the aid of the AC source output to provide an inherent filtering operation.

According to another implementation, a transducer assembly for measuring, preferably in a non-contacting fashion, torque in a rotating shaft, comprises an erase head for cleaning a zone of the shaft as it rotates, a write head downstream of the erase head in the direction of rotation to write a magnetic track onto the cleaned zone, said track having a given width, a pair of read heads spaced in an axial direction to respond to the magnetic track, said read heads being disposed on, toward or adjacent opposite sides of the track to generate respective signals, and differential means responsive to said respective signals to provide a signal dependent on torque in the shaft. It is preferred to energise the write head with an AC signal,

preferably a pulsed signal, to detect the AC outputs of the read heads derived from the AC modulated track. The detection can be done in a frequency-selective manner to enhance discrimination from other signal fields that may be present. It is preferred that the write head be oriented with the head gap in the circumferential or tangential direction.

Aspects and features of this invention are set forth in the claims following this description.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described by way of example and with reference to the accompanying drawings wherein:

Figures 1 to 3 illustrate measurement of shaft torque using circumferential magnetisation;

Figures 4 and 5 illustrate measurement of shaft torque using longitudinal magnetisation;

Figure 6 shows the longitudinal magnetic flux developed in the shaft of a typical electric motor;

Figures 7 and 8a show apparatus for cancelling an interfering magnetic field generated by an electric motor according to a first embodiment of the invention;

Figure 8b is an end view of the shaft shown in Figure 8a;

Figures 9a and 9b show side and end views of a shielded and actively compensated transducer in accordance with a second embodiment of the invention;

Figures 10a and 10b show side and end views, respectively, of apparatus for measuring shaft torque using a magnetic

field in the shaft according to a third embodiment of the invention;

Figure 11 shows a deflected magnetic field in the shaft of Figure 10a;

Figure 12 shows an arrangement for eliminating the effects of an interfering magnetic field by using a transducer system operating at a selected frequency in accordance with a fourth embodiment of the invention; and

Figures 13a and 13b show side and end views of an arrangement for measuring shaft torque using magnetic erase, read and write heads adjacent a shaft, according to a fifth embodiment of the invention.

Figures 1 to 3 illustrate detection of shaft torque using the technique of circumferential magnetisation referred to above. Fig. 1 illustrates the circumferential field, indicated by arrow, 2 under no torque condition in a transducer region 3 of a shaft 4 rotatable about axis A-A. Fig. 2 illustrates the closed loop nature of the field in a surface adjacent zone of the region shaft 3. The region 3 exhibits magnetoelasticity. Under "no torque" the circumferential field 2 in region 3 is entirely contained in the region 4: there is no external fringe field. Under torque, as seen in Fig. 3 the field 2 is skewed to produce an axially-directed North-South (NS) magnetisation whose polarity and magnitude are dependent on the direction (clockwise or counterclockwise) of the torque and its magnitude. The axial magnetisation emanates an external fringe field dependent on torque which is measurable by a sensor 7, or more usually by a sensor arrangement comprising a plurality of sensors. The sensor(s) may be of the Hall-effect or magnetoresistive type but preferably are of the saturating core type connected in a circuit such as disclosed in published PCT application WO98/52063.

Figures 4 and 5 demonstrate detection of shaft torque using longitudinal magnetisation of a region 3' of the shaft 4. The region 3' is of magnetic material. The longitudinal field 8 lies along the shaft in a surface adjacent annulus forming a torus of magnetic flux which closes mainly in an inner zone of the regions 3' to form a closed toroidal loop. The surface field all lies in the same direction. There is a small quiescent longitudinal fringe field 10 that leaks from the shaft as seen in Fig. 4. In the form of longitudinal magnetisation being discussed, under torque, the field 2'skews (Fig. 5) as indicated by the dashed arrows 2"and produces a small transverse or circumferential component detectable by sensor 22: the longitudinal component is detectable by sensor 21. The sensors of the types already mentioned have directional responses and are oriented to be responsive to the desired field component.

Further information on the form of longitudinal magnetisation discussed above and the means of producing it is found in International patent application PCT/GB00/03119 (WO) which is incorporated herein by reference.

Attention can now be given to problems which arise when the shaft 4 is driven, and thus put under torque by a machine such as an electric motor.

An electric motor 63 is diagrammatically shown in Fig. 6. It has an integral output shaft 61 which is susceptible to providing a path for magnetic forces generated by the motor during its operation. Depending on the specific design of the motor and of the shaft 61 driven thereby some magnetic field can exit the motor assembly (unintentionally or inadvertently) through the drive shaft 61 of the motor 63 as indicated by arrows 60. This assumes the shaft is of a ferromagnetic material and is

capable of supporting a transducer region of the kind described above in an integral portion of the shaft.

When trying to measure the mechanical torque generated by the electric motor 63 in the shaft 61 by using the methods described above with an appropriate transducer assembly 62 which includes a magnetised transducer region 64 of shaft 61, the motor induced longitudinal magnetic flux 60 present in the transducer region 64 of drive shaft 61 can generate large sensor offset signals. The drive shaft itself provides the magnetic sensor host for the transducer region. These offset signals are modulated by the changes of the mechanical load on the motor axis and the supplied electrical current to the motor. The offset is therefore dynamic and cannot be easily compensated for.

A solution to the problem explained with reference to Fig. 6 is seen in Fig. 7. A pair of coils L1 and L2 are axially spaced about transducer region 64 and they are energised to provide a longitudinal magnetic field in region 64 that counteracts the field due to the motor 63.

As indicated in Fig. 7, the level of the interfering magnetic field strength may be measured in real time by an axially oriented sensor (such as sensor 7 or 21) forming part of the transducer assembly 62 and controlling a compensating current source 65 that energises coils L1 and L2 connected in series with a current I of a magnitude to cancel the motor induced field 60.

To allow measurement of longitudinal (axially-directed) field components of the transducer region, the compensating action can be set up under no torque conditions for circumferential magnetisation, then held at that value. Otherwise the adjustment can be done manually to establish a preset current value. The technique most

suitable will depend on the circumstances of each individual installation.

Figs. 8a and 8b illustrate a preferred implementation of the active compensation technique of Fig. 7. These figures show a collar structure which finds application in various other embodiments of the invention described below. In Figs. 8a and 8b the shaft 61 is collared at 20 to produce a recess 25 the base of which extends about transducer region 64 and which aids in causing internal longitudinal flux to "leak" externally to the shaft and be detectable. The external longitudinal flux is detected by sensors 24 which may be in controlling a current generating means for energising coils L1, L2 to counteract the external longitudinal flux as previously described and/or as part of the torque measurement process. If the region 64 is longitudinally magnetised torque is measured using sensor 23 (preferably a pair of diametrically opposed sensors) to detect a torque-dependent component of the external flux. In Fig. 7 the transducer region 64 lies between coils L1 and L2 within the sensor arrangement which is adjacent to but does not contact the shaft. Similarly in Figs. 8a and 8b the magnetised transducer region is located in the region forming the base of recess 25 with non-contacting sensors 23 and 24. The collar structure is applicable to a transducer region circumferentially or longitudinally magnetised. In Figs. 8a and 8b the sensor arrangement is appropriate to longitudinal magnetisation.

Figures 9 and 9b show an arrangement similar to that of Figures 7 and 8 in that it seeks to back off or nullify the motor leakage flux in shaft 61. It is intended for higher levels of flux. L1 and L2 are energised as before, for example in dependence on the flux sensed at 24. A housing 70 of magnetic material providing a magnetic shield encloses the transducer region 64 of the shaft 61

and the adjoining coils L1, L2. The shield 70 is apertured at 72a and 72b for passage of the shaft and these apertures provide axially-spaced, magnetic poles of opposite polarity between which the collared region 64 is located. The poles act on the shaft 61 to induce a longitudinal flux through the transducer region 64 to counteract longitudinal flux in the shaft due to the driving motor. The poles 72a, 72b are magnetised by one or more coils wound about the housing 70. Specifically a pair of coils L3 and L4 are shown and L3/L4 are energised by current I' dependent on the flux sensed by 24. The poles concentrate the shield flux. The polarity induced is the same as the coils L1 and L2. For a small shaft diameter the magnetic shield and coil L3/L4 structure enables higher ampere turn ratings to be accommodated for large leakage fluxes. The combination of L3/L4 and shield on one hand and the coils L1/L2 on the other may be applied separately. The shield arrangement may be advantageous when there are other stronger sources of stray magnetic field in the vicinity of the transducer. For example the shield may protect the transducer from fields of the order of 100 or more Gauss, whilst coils L1 and L2 typically protect against fields of the order of tens of Gauss.

A different approach is adopted in the apparatus of Figs. 10a, 10b and 11. Rather than nullifying the longitudinal flux from motor it is instead used as the transducer flux source in a longitudinal magnetisation type measurement. Here again a collared structure 20 aids in outwardly deflecting the longitudinal flux in the region 64 for producing a longitudinal (axial) directed external field. The longitudinal sensors 24 measure the longitudinal flux (of whatever value). The transverse sensor(s) 23 measures the circumferential component. The torque calculation is made independent of the actual flux in the shaft by using this as a reference. The measurement from sensors 24 is

used as a reference against which the torque-dependent component value from sensor(s) 23 is measured.

The axial component (measured by 24) is used to determine the maximum available field strength to measure torque at the sensor region. The result of this measurement is used to control the gain of processing circuitry for providing a signal representing torque. The greater the longitudinal magnetic field 60, the higher the sensitivity of the magnetic field measured by the circumferentially arranged magnetic field sensors. Therefore the amplification gain in the signal conditioning electronics for the circumferentially magnetic field sensors need to be reduced in proportion to an increase in the longitudinal magnetic field.

As shown in Fig. 11, the longitudinal field 60 that extends through the region 64 will be deflected as indicated at 60a in relation to the applied torque forces on the drive shaft 61. The whole shaft effectively acts as a force sensor. The greater the torque, the larger the circumferential component of the field, measured by sensor 23.

In the embodiments of Figure 7 and Figures 8a and 8b, the current in coils L1 and L2 is applied so that the loop fields compensate or nullify the interfering field. A similar coil arrangement to that illustrated in Fig. 7 and in Figs. 8a and 8b can be used in a different way in a technique which aims to eliminate the effect of the interfering field from the torque-sensing operation rather than cancelling or compensating the interfering field. This is illustrated in Fig. 12.

In Fig. 12 the coils L1 and L2 are not energised in dependence on a sensed field but to the contrary are energised to create a field distinguishable from

interfering fields. To this end the coils L1 and L2 are connected to an AC source 30, preferably a pulse-type source, to induce an alternating magnetic field in the transducer region 32 between the coils. This is a longitudinal field. The source frequency should avoid a relationship with main supply frequencies (50 or 60 Hz) or any other frequency imposed by the operation of the motor or machine with which the shaft is associated. Conveniently the source frequency is in the audio range, say between 500 Hz and 10 kHz. A frequency around 1 kHz would be suitable. It is also a frequency within the sensing capability of saturating-core type of sensors. Hall effect or magnetoresistive types of sensor may be expected to have a higher frequency response but frequency limitations may also be imposed in driving the coils L1 and L2.

The alternating magnetic field provides an alternating torque-dependent component at the source frequency sensed by the sensor(s) 23. The total torque-dependent component to which sensor(s) 23 responds may include a DC component from a machine-induced interference field or another AC component associated with the main frequency or a frequency emanating from the motor driving the shaft. The wanted source frequency component is extracted from the unwanted noise components by a filter 34 feeding or included within signal-processing unit 38 from which the torque representing signal T is obtained. The filter 34 may be realised in hardware or software and the filter frequency driven from the source as indicated by the chain line 36 to ensure the filter tracks the source frequency. Synchronous detection in which the detector is drive by a signal from source 30 may be employed. All these techniques are well-known.

The sensors (24) can be used to derive a reference signal for deriving the torque from the torque-dependent

component provided by sensor 23. The reference signal in this case is a component at the source frequency and is subject to filtering at 31 in the same way as the torque-dependent component is filtered. To this extent operation is similar to that of the embodiment of Figs. 10a, 10b and 11.

Another approach to torque measurement is illustrated in Figs. 12a and 12b. As the shaft 61 rotates a circumferential band 16 is cleaned by a magnetic erase head(s) 12 of the kind used in magnetic recording. Following the erase head (downstream), a write-head 13 writes a magnetic track 15 (of any kind) of width w. The shaft should preferably be rotating at at least 100 rpm when using this technique. The write-head 13 is oriented to have the head gap transverse to the axis of rotation of the shaft and preferably perpendicular to the axis of rotation so that the gap lies tangential or circumferentially disposed with respect to the rotating shaft surface.

The two read-heads 14a and 14b are spaced relative to the width w to give no signal when the shaft is barely rotating or known balanced signals that can be nulled. As torque builds in the shaft it has been found that the signals from the read-heads 14a and 14b become unbalanced to an extent dependent on the value of the torque. This reaction to torque is as if the magnetised track 15 or the flux associated with it is slightly deflected one-way or the other dependent on direction of rotation to produce an unbalance output from the read-heads 14a and 14b that is a measure of torque.

The write-head 13 may preferably modulate the track 15 in some way to provide a signal at each read head that can be separated from noise. To this end the write-head can be energised with a pulse waveform at a given frequency.

Filtering at the source frequency is applied to the read-heads 14a and 14b. This frequency-selective mode of operation is similar to that described for the embodiment of Fig. 12., The read pulses in Fig. 13 will be delayed with respect to the write pulses to an extent which is usable as a measure of the rate of rotation.

CLAIMS

1. A torque transducer for measuring torque in a rotating shaft (61) of the kind having a transducer region (64) in which a magnetic transducer field is established and at least one non-contacting sensor (23, 24) adjacent the transducer region to develop a torque-dependent signal, wherein in operation the shaft is subject to longitudinal flux (60) generated by means (63) external to the transducer region (64), characterised by and means (65) magnetically coupled to said shaft (61) to generate a compensating flux to counteract said longitudinal flux at the transducer region (64).

2. A torque transducer as claimed in Claim 1 further comprising means (24) for sensing and providing a signal dependent on said longitudinal flux, the means (65) for generating the compensating flux being responsive to said signal.

3. A torque transducer as claimed in Claim 1 or 2 wherein said means for generating the compensating flux comprises at least one current-carrying coil (L1, L2) about the shaft to be magnetically coupled thereto.

4. A torque transducer as claimed in Claim 1 or 2 said means (65) for generating the compensating flux comprises a magnetic structure (70) having poles (72a, 72b) spaced along the shaft (61) and at least one current-carrying coil (L3, L4) wound on said magnetic structure (70).

5. A torque transducer for measuring the torque in a rotating shaft (61) which, in operation, has a longitudinal field (60) extending therealong, wherein at least one sensor (23) is placed in non-contacting fashion adjacent a portion of the shaft to sense and provide a signal dependent on a transverse component of flux arising from the longitudinal flux due to the torque in the shaft (61).

6. A torque transducer as claimed in Claim 5 in which a further non-contacting sensor (24) is mounted to sense the longitudinal flux to provide a reference signal

dependent thereon for use in obtaining a value for the torque in the shaft.

7. A torque transducer for a rotating shaft (61) comprising flux generating means (L1, L2) for generating a magnetic flux extending longitudinally in a portion (64) of the shaft, said flux generating means (L1, L2) being magnetically coupled to said shaft at axially spaced locations between which said portion (64) is situated, at least one sensor (23) placed in non-contacting fashion adjacent said portion to provide a signal dependent on a transverse component of flux arising from the longitudinal flux in said portion (64) due to the torque in the shaft (61),

said magnetic flux generating means being operable to generate an alternating magnetic field at a selected frequency, and said at least one sensor signal being processed by frequency selective means (34) operable at said selected frequency to provide a signal representing torque in the shaft (61) derived from said alternating magnetic field.

8. A torque transducer as claimed in Claim 7 in which said shaft (61) transmits in operation another longitudinal flux (60), not generated by said flux generating means (L1, L2: L3, L4) said selected frequency enabling the signal dependent on the transverse component of flux to be separated from any signal due to said other longitudinal flux in processing by said frequency selective means (34).

9. A torque transducer as claimed in Claim 8 in which said flux generating means operates in a pulsed mode.

10. A torque transducer as claimed in Claim 7, 8 or 9 in which said flux generating means comprises a pair of spaced coils (L1, L2) wound about said shaft (61) and between which said portion (64) is situated and means (30) for energising said coils (L1, L2) at the selected frequency.

11. A torque transducer as claimed in Claim 7, 8 or 9 in

which said flux generating means comprises a magnetic structure (70) having a pair of spaced poles (72a, 72b) which magnetically coupled to said shaft (61) and between which said portion (64) is situate, at least one coil (L3, L4) would on said magnetic structure, and means (30) for energising said at least one coil (L3, L4) at the selected frequency.

12. A transducer assembly for measuring, preferably in a non-contacting fashion, torque in a rotating shaft (61), the assembly comprising an erase head (12) for cleaning a zone (16) of the shaft as it rotates, a write head (14) downstream of the erase head (12) in the direction of rotation to write a magnetic track (15) of a given width onto the cleaned zone (16), a pair of read heads (14a, 14b) spaced in an axial direction to respond to the magnetic track (15), said read heads (14a, 14b) being disposed on, toward or adjacent opposite sides of the track (15) to generate respective signals, and differential means responsive to said respective signals to provide a signal dependent on the torque in the shaft (61).

13. A transducer assembly as claimed in Claim 12 in which said write head (13) is energised with an AC signal at a selected frequency.

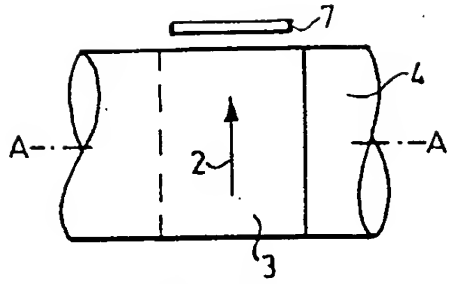


Fig.1.

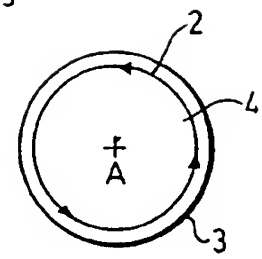


Fig.2.

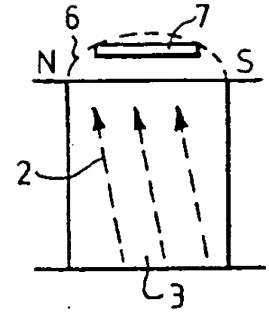


Fig.3.

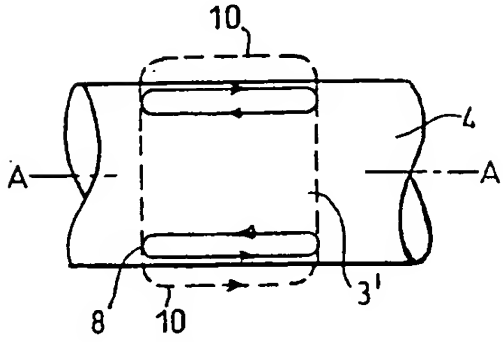


Fig.4.

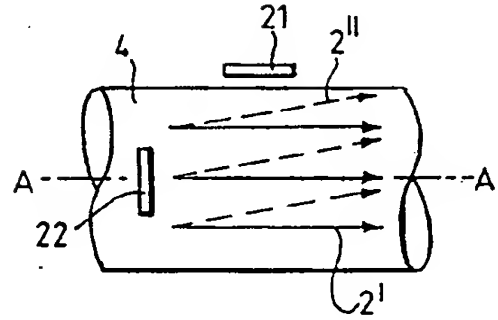


Fig.5.

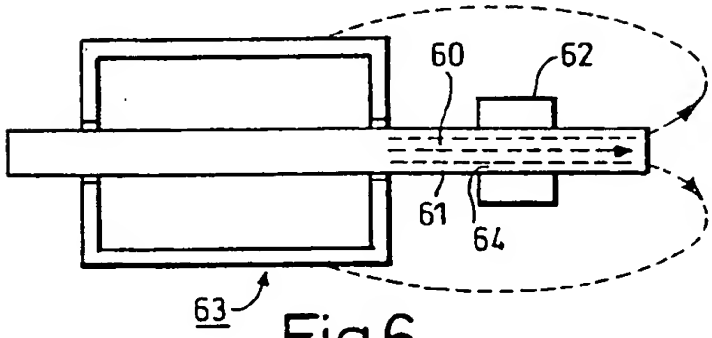


Fig.6.

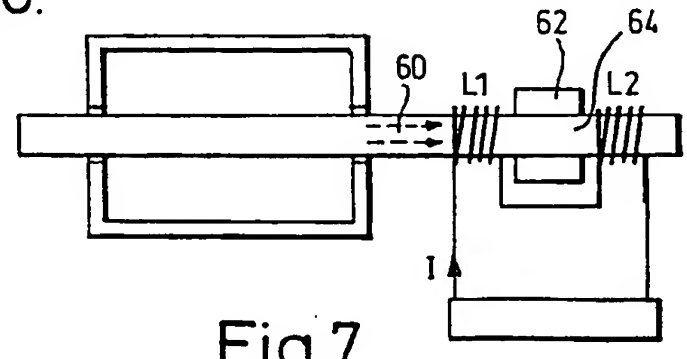


Fig.7.

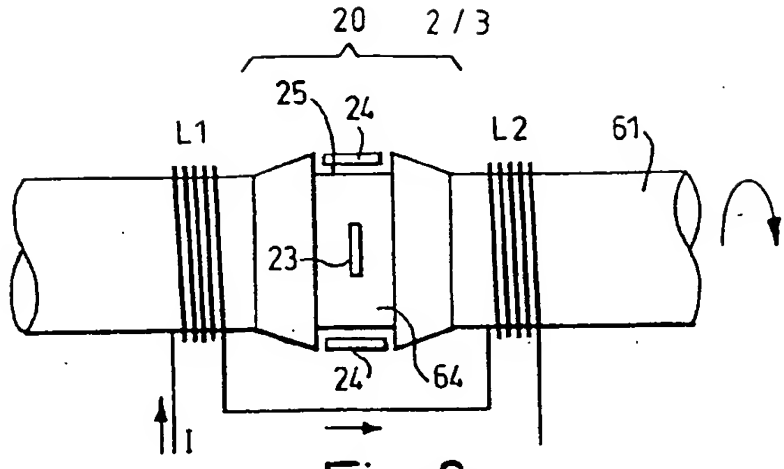


Fig.8a.

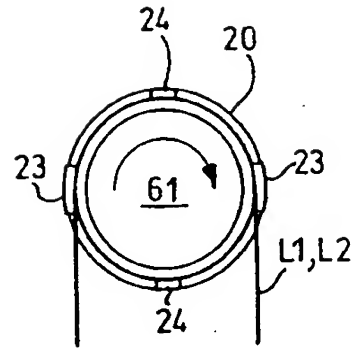


Fig.8b.

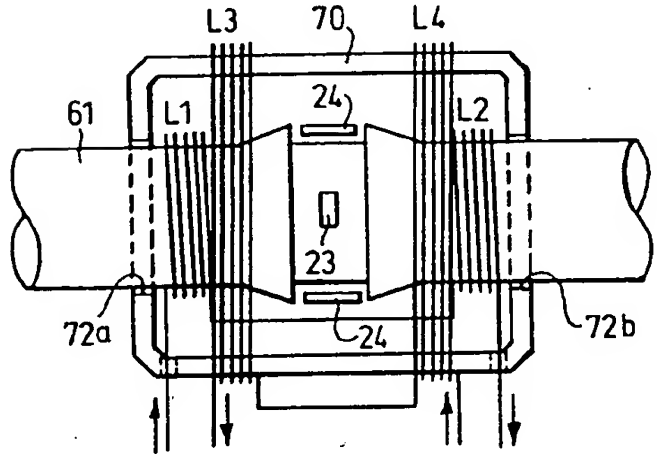


Fig.9a.

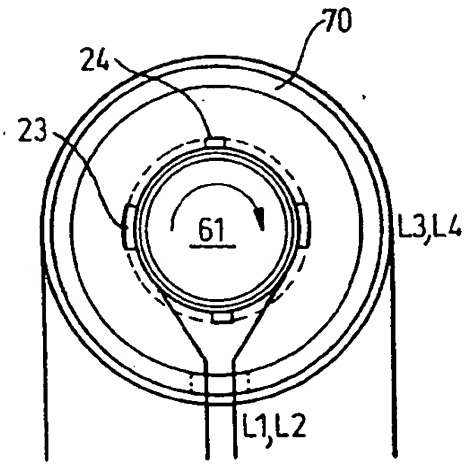


Fig.9b.

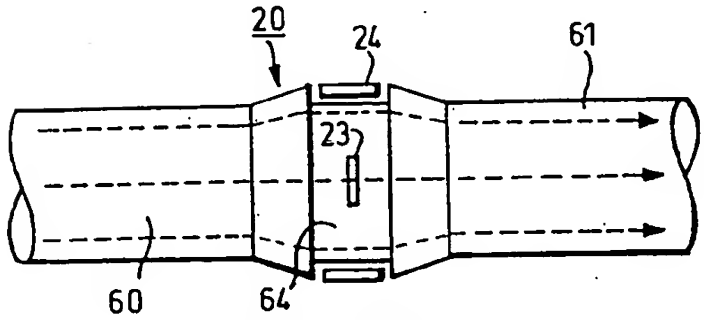


Fig.10a.

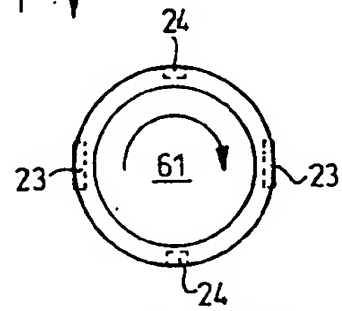


Fig.10b.

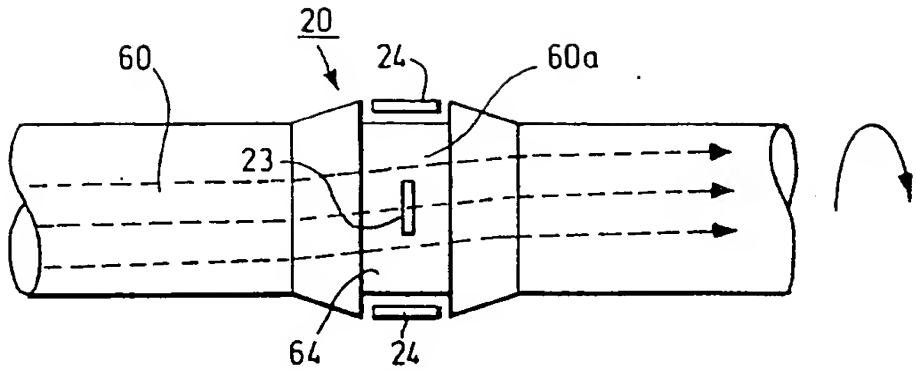


Fig.11.

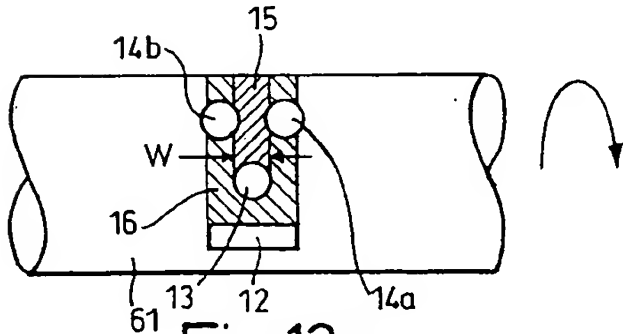


Fig.13a.

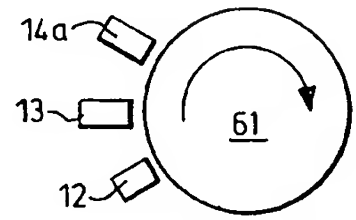


Fig.13b.

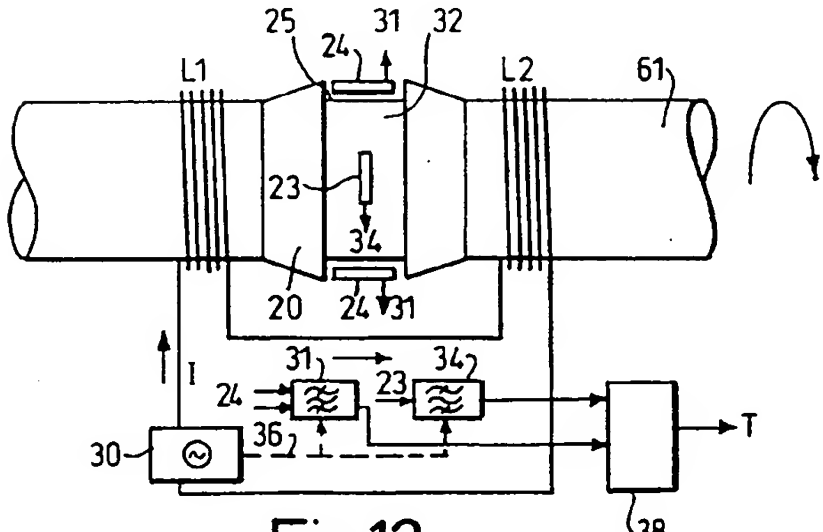


Fig.12.

INTERNATIONAL SEARCH REPORT

Int. ional Application No
PCT/EP 00/10022

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01L3/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 434 089 A (ASEA BROWN BOVERI) 26 June 1991 (1991-06-26) the whole document	1-11
X	GB 968 503 A (BRISTOL SIDDELEY ENGINES LTD) 2 September 1964 (1964-09-02) the whole document	12,13

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 February 2001	21/02/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Nobrega, R.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. tional Application No
PCT/EP 00/10022

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